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UNIVERSITI TEKNOLOGI PETRONAS

MATHEMATICAL MODELING, CONTROL AND SIMULATION OF PETROLEUM DISTILLATION COLUMN

By

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MATHEMATICAL MODELING, CONTROL AND SIMULATION OF PETROLEUM DISTILLATION COLUMN

By

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A Thesis
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PERAK

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DECLARATION OF THESIS

Title of thesis | **Mathematical modeling, control and simulation of petroleum distillation column**

I **KHOO BOO KEAN**

hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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ABSTRACT

Distillation column processing is the most vital separation technology in the petroleum industries for purification of final products. Distillation columns are made up of several components each of which is used either to transfer heat energy or to enhance mass transfer. An inclination to controlling distillation columns in a manner that is economically efficient depends much on the selection of reliable systems. This thesis presents a detailed methodology to derive a calculation procedure of the distillation column to build a gas processing plant to raise the utility value of condensate. The quality of the output products are the purity of the distillate product should higher than or equal to 98% and the impurity of the bottoms product, should less or equal than 2%. The L-V structure, which is called energy balance structure, is considered as the standard control structure for the distillation system design. In this design system the liquid flow rate and the vapor flow rate are inputs variable parameters to determine the purity and impurity of the output product concentration. Therefore, an appropriate control system is essential for designing stage. The main role of the controller is to sustain the output concentration despite the disturbance in the feed flow and the feed concentration. This thesis will deliberate a control model system development via three steps. Firstly, develop a calculation procedure of a distillation column for simulation and analysis. Second for the controller design: a reduced-order linear model is derived such that it best reflects the dynamic of the distillation process and used as the reference model for a model-reference adaptive control (MRAC) system and thirdly, verify the ability of a conventional adaptive controller for the distillation system when dealing with process mismatch and feeding disturbances. However, in this study, the system identification is not fully employed as the actual production factors and designed structures are not validated. In this research, the calculations and simulations are implemented by using MATLAB (version 7.0) software package.

ABSTRAK

Proses penyulingan atau pengasingan petroleum merupakan salah satu kaedah penapisan yang penting dalam petrokimia industri pada masa kini. Oleh itu, pemilihan sistem penapisan yang terbaik akan dapat menjimatkan kos operasi dan juga masa. Kajian saya ialah untuk menghasilkan satu kaedah matematik bagi proses pengasingan yang akan digunapakai dalam loji penapisan minyak untuk mengekalkan ataupun meningkatkan tahap kepekatan mutu produk pengeluaran. Mutu produk pengeluaran ditentukan oleh "purity" yang perlu melebihi ataupun sama dengan 98% dan "impurity" yang perlu melebihi ataupun sama dengan 2%. Kaedah kajian saya ini akan menerangkan kaedah terperinci bagaimana untuk menghasilkan sebuah model matematik berdasarkan struktur tenaga (L-V). Dalam sistem model ini, terdapat dua pembolehubah masuk iaitu "liquid flow rate" dan "vapor flow rate" yang dimana ia akan menpengaruhi secara langsung terhadap mutu hasilan produk keluaran. Oleh sedemikian, pembangunan sebuah model kawalan yang lebih berkesan adalah amat penting pada peringkat perancangan. Fungsi utama sebuah "controller" ialah untuk mengawal dan menjamin mutu produk keluaran supaya tidak dipengaruhi oleh sebarang gangguan luaran. Untuk menghasilkan sebuah sistem kawalan model yang efisien ianya boleh dilaksanakan melalui tiga fasa. Fasa pertama, membangunkan sebuah model matematik untuk tujuan simulasi dan analisi. Fasa kedua, untuk rekabentukkan sebuah "controller" linear model yang akan digunakan sebagai model kawalan rujukan MRAC dan fasa yang ketiga ialah daripada model kawalan rujukan MRAC ini akan digunakan untuk menyiasat keboleharapan dan penyesuaikan diri untuk mengekalkan mutu hasilan produk apabila terdapat gangguan luaran yang tidak menentu dan juga variasi yang berlaku dalam proses pengasingan ini. Kajian saya ini dijalankan dengan mengunakan kaedah simulasi dan analisi berpandukan MATLAB versi 7.0 semata-mata.

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NOMENCLATURE

X_B	Bottom products of the distillation column
$R\ or\ L$	Liquid stream withdrawn from the drum and returned to the top tray of the distillation column as reflux
Y_1	Composition of the vapor leaving the top tray
X_D	Liquid product and reflux of the distillation column
x_n	Liquid composition on n* stage (mole fraction of light component)
y_n	Vapor composition on n* stage (mole fraction of light component)
α	Relative volatility
C_F	Feed rate of the feedstock
EFV	Equilibrium flash vapor
V_F	Feeding flow rate during vapor phase.
L_F	Feeding flow rate during liquid phase.
V_f	Vapor flow from bottom column
R_f	Internal reflux descending across the feed section
M	Holdup on tray
M_B	Holdup in column base
M_D	Holdup in reflux drum
D	Distillate flow (Kmole/hr)
B	Bottom flow (Kmole/hr)